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AGREEMENT

FOR

NASA/OAST-USAF/AFSC SPACE INTERDEPENDENCY

ON SPACECRAFT-ENVIRONMENT INTERACTION

APPROVAL: MAY 15 1980

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1.0 BRIEF TECHNICAL SUMMARY

The objective of this investigation is to develop technology to control interactions between large spacecraft systems and the charged particle environments of space. This technology will support NASA/DOD operations of the Shuttle/IUS and AFSC Space Division's Advanced Space Defense Program concepts, Strategic Satellite System, MSP/Mini-Halo and the DARPA/RADC Space Based Radar technology program.

To achieve this objective, a joint AF/NASA comprehensive research and technology program on spacecraft-environment interactions is being undertaken. This program consists of combined contractual and in-house efforts aimed at understanding spacecraft-environment interaction phenomena and relating ground test results to space conditions. There is a concerted effort to identify project-related environmental interactions of concern. There is a materials investigation to measure the basic properties of materials and develop or modify materials as needed. There is a ground simulation investigation to evaluate basic plasma interaction phenomena and provide inputs to the analytical modelling investigation. Systems performance is evaluated by both ground tests and analysis. There is an environmental impact investigation to determine the effect of future large spacecraft on the charged particle environment. Finally, there will be space flight investigations to verify the results of this technology investigation. The products of this research and technology program are test standards and design guidelines which will summarize the technology, specify test criteria and provide techniques to minimize or eliminate system interactions with the charged particle environment.

The investigation is coordinated by a Spacecraft-Environment Interaction Program Steering Committee which will incorporate into this investigation the requirements of both the AF and NASA.

2.0 SPACECRAFT-ENVIRONMENT INTERACTION STEERING COMMITTEE

2.1 Function

The function of this committee is to coordinate all phases of the investigation, review progress and to direct changes, as required, to satisfy the needs of the AF and NASA. This committee shall meet annually, at least, to review the program, to resolve pending action items, to receive reports from Working Group Chairmen and to issue required action items. The minutes of these meetings will be issued.

2.2 Reporting

The committee will report to the NASA (OAST) and AFSC/DL Space Technology Group meetings.

2.3 Membership

The Steering Committee consists of the following members:

Co-Chairmen: Charles P. Pike (AFGL)
Robert C. Finke (NASA-Lewis Research Center)

Members:

Wayne Hudson, HQ	W. Lehn, AFWAL
J. McCoy, JSC	A. Frederickson, RADC
C. R. Chapell. MSFC	
N. J. Stevens, LeRC	
E. Pawlik, JPL	

2.4 Working Groups

The Steering Committee is advised by Working Groups. These Working Groups have been established to review, plan and coordinate investigations in specific areas, recommend new directions as required and make periodic progress reports to the Steering Committee. The Working Groups will function to keep the various organizations, both those within the formal Spacecraft-Environment Interaction Program and others, coordinated in their various activities.

The Chairman of each Working Group is appointed by the Steering Committee. He has the responsibility of selecting members of the Working Group from the technical experts of government, industrial or university communities.

3.0 JUSTIFICATION

There is a trend towards missions/programs using very large spacecraft in the mid to late eighties. These missions are initially planned for low Earth (Shuttle) orbits with the possibility of moving to geosynchronous orbit altitudes. Typical examples of these missions include communications platforms and space-based radar. The now-concluding AF/NASA Spacecraft Charging Technology Investigation has shown that the environmental charged particle fluxes can act on spacecraft surfaces and influence system performance. These new, large spacecraft can have potentially serious interactions at all altitudes and these interactions must be evaluated. The proposed structures have dimensions larger than characteristic plasma lengths and differential surface charging is possible. The motion of such a large structure in the Earth's magnetic field will induce electromagnetic forces on the structure. Since these structures are designed for low density materials, electromagnetically induced stress can impact the mechanical design.

There is also a trend toward high power modules for space applications. Plans have been established for 25 kW modules in the early eighties, expanding to 500 kw modules in the late eighties. At these power levels the operating voltages can be expected to be increased to levels greater than the present range of 30 to 100 volts to increase system efficiency. This elevation of operating voltages means that the probability for interactions between the biased surfaces and the plasma environment can be increased. Laboratory tests on small solar array samples have indicated that possible interactions include the establishment of parasitic current loops through the environment (resulting in power losses), arcing at negative potentials,

and disproportionate current collection through holes in insulation to biased surfaces underneath. These effects can adversely influence the operation of space power modules and must be understood prior to building high powered systems.

As an outgrowth of the AF/NASA Spacraft Charging Technology Investigation, it is possible to predict the electric fields surrounding the spacecraft due to the surface charging. Using this technique it will be possible to assess the impact of a spacecraft on the measurements provided by spacecraft sensors and instruments; hence, significantly improving confidence in the data.

There is also a growing concern for the influence that the very large structures proposed for future applications can have on the charged particle environment. The tenuous balance established by nature may be upset when these systems are inserted into Earth orbits.

4.0 SPACECRAFT-ENVIRONMENT INTERACTION TECHNOLOGY INVESTIGATION

The overall objective of this investigation is to develop the technology for controlling spacecraft system interactions with the charged particle environment of space. The technology developed in this investigation will support proposed AF/NASA space mission concepts into the nineties.

The initial emphasis in this investigation will be on low Earth orbit (LEO) conditions. The proposed missions will be catalogued, engineering specifications for the charged particle environment established and possible interactions identified. The ground technology investigation will concentrate on determining and modelling plasma phenomena and then extrapolating these results to system interactions and performance in space. Applicable techniques available to the participants will be utilized.

The environmental interactions for large systems operating in geosynchronous conditions will be evaluated after the low Earth orbit study. The geosynchronous environmental investigation will utilize the LEO study results as well as applicable techniques from the AF/NASA Spacecraft Charging Technology Investigation.

In both the LEO and geosynchronous environmental interactions investigation the effect of large systems on the charged particle environments will be evaluated as well as the effect of the environment on the system performance.

Space flight experiments will be conducted to verify the results of the ground-based technology investigation of the environmental interactions. While these space experiments will be coordinated with the ground-based study, they will be proposed as separate experiments and funded independently.

The output of this investigation will be a series of Test Standards and Design Guideline documents. These will be issued in a preliminary form early in the investigation and upgraded as the study continues. This investigation is planned as a 9-year technology program starting in FY 81 and running through FY 89. The major milestones for this investigation are shown in Fig. 1.

5.0 TECHNICAL APPROACH

In this section the technical approach to accomplish this technology investigation is discussed. For each element of the investigation the approach will be summarized and the known tasks identified. The agency or agencies responsible for directing and coordinating the work under each task will be given. While the prime responsibility is assigned to one agency, the expertise of other agencies will be utilized.

5.1 User Requirements

It is necessary to identify those missions or projects that could benefit from the technology that will be developed by this investigation and to incorporate their requirements into this study. This will be accomplished by maintaining close liaison with the government funding sources and project offices. Potential applications of the technology have been identified as:

- Large space structures
- Large multikilowatt space power systems
- Large high power communications satellites
- Large surveillance satellites
- Scientific spacecraft (charged surface effects on instrument behavior)

The primary interactions to be evaluated have been tentatively identified as:

- Large space system interactions. These interactions involve the possible effects due to the motion of a large body in the space environment and due to material reactions to the charged particle fluxes.

- Biased systems/charged particle interactions. These interactions include spacecraft systems that generate or use high voltage exposed to space. Such spacecraft systems as high voltage space power modules and communications satellites fall into this category.

- Scientific instruments and sensor interactions. An evaluation of the impact of electric fields surrounding a spacecraft on the behavior of scientific instruments and sensors will be conducted.

- Large structure interactions on the environment. The presence of the proposed large structures may affect the environment. Such effects must be evaluated.

Other interactions that can be evaluated are:

- Enhanced particle environment interactions. These interactions involve spacecraft particle sources that can be ionized and increase the charged particle environment around the spacecraft. Close coordination will be maintained with the existing AF/NASA Spacecraft Contamination Investigation.

- High energy particle interactions. Penetrating radiation effects will be evaluated in this study only insofar as they can influence charging phenomena (e.g., internal spacecraft charging, radiation enhanced conductivity in materials). Close coordination will be maintained with other groups conducting radiation damage evaluations.

The specific tasks and responsible agencies are:

5.1.1 Task 1: Coordination and Overview

The coordination of the user's needs and the incorporation of these needs into the investigation will be the responsibility of the Steering Committee.

5.1.2 Task 2: AF and NASA Contacts

The various agencies will maintain a close relationship with the projects managed within their respective agency to determine user needs for this investigation and report those needs to the Steering Committee for coordination and incorporation into this investigation.

5.2 Environment Specifications

Under this element the natural environment will be investigated and engineering specifications generated or updated as appropriate. The impact of large spacecraft on the environment shall also be investigated and evaluated.

The specific tasks and responsible agencies are:

5.2.1 Task 1: Natural Environment Specification

The available data for the low Earth orbit, geosynchronous and solar wind charged particle environments will be reviewed. An engineering specification for these regions will be generated and made available to all parties concerned with environmental interactions. This work will be the responsibility of AFGL.

5.2.2 Task 2: Planetary Environment Specification

The available data for the planetary environments will be reviewed. An engineering specification for these environments will be generated

and made available to all parties concerned with environmental interactions. This work will be directed by JPL.

5.2.3 Task 3: Enhanced Spacecraft Environment Specification

The available data on possible outgassing or other sources that can be ionized and enhance the natural charged particle environment will be reviewed. An engineering specification for this enhanced environment will be generated and made available to all parties concerned with spacecraft environmental interactions. Close coordination will be maintained with the AF/NASA Spacecraft Contamination Investigation to avoid duplication. This work will be the responsibility of JPL.

5.2.4 Task 4: Environmental Impact

Using the environmental specifications and the proposed large spacecraft plans, the possible alterations to the natural environment due to the presence of the spacecraft will be investigated and evaluated. This work will be the responsibility of AFGL.

5.3 Materials Investigation

In this program element the basic properties of typical spacecraft materials, exposed to the space environment, will be determined and new or modified materials will be developed.

The specific tasks and responsible agencies are:

5.3.1 Task 1: Material Property Determination

The classical properties of typical spacecraft materials will be determined as a function of the material parameters and environmental fluxes. The properties to be determined are those which influence the surface potential of the material, e.g., secondary emission, backscatter, deposition and photoemission. Electron, proton and photon fluxes as determined by the environmental specifications are to be considered. This work will be the responsibility of JPL.

5.3.2 Task 2: New or Modified Materials Development

In this task materials having selective properties will be developed as a means of controlling detrimental effects of spacecraft environmental interactions. The required properties for these materials, including advanced composite materials, will be defined from the interaction studies. The materials will be developed and tested to show that they will meet the requirements. This task will be the responsibility of AFWAL.

5.4 Ground Simulation Investigation

Under this technology element existing facilities will be utilized to simulate the space plasma environment and interactions will be studied experimentally.

The specific tasks and responsible agencies are:

5.4.1 Task 1: Basic Interaction Studies

This task will be divided into several subtasks each devoted to the study of a particular aspect of the interaction phenomena.

a. Interactions between the charged particle environment and insulator/biased conductor surfaces will be investigated. Here the interest is in the growth of electric fields in the insulator surfaces as a function of the material properties, charged particle density and voltage. This work will be conducted by the LeRC.

b. Plasma sheath growth phenomena will be investigated. Interactions between large structures moving through the charged particle environment will be investigated. Plasma wake and ram effects and sheath growth will be evaluated. Responsibility for this work will be divided between MSFC for NASA mission requirements and AFGL for unique AF mission requirements.

c. Discharges resulting from environmental interactions will be characterized. Both radiated and conducted characteristics will be determined. This work will be conducted by JPL.

d. Penetrating radiation studies will be conducted to evaluate radiation induced charging interactions. This work will be conducted by RADC.

5.4.2 Task 2: Large High Voltage Power System Studies

In this task the basic interaction study results from section 5.4.1 will be applied to the design of large power systems for space applications. The interactions actions will be scaled to the large size of a typical power system, the environmental conditions will be scaled from ground conditions to space, and the effects of the environment on system performance will be evaluated. Means of controlling detrimental interactions will be devised. Wherever possible, experiments will be conducted to demonstrate that the interactions can be controlled. This work will be conducted by JSC for NASA missions and by AFWAL for AF missions.

5.4.3 Task 3: Large Space Structure - Environment Interaction Experimental Studies

a. The large structures proposed for future space applications will interact with the environment inducing among other things electrostatic stresses that must be considered in the design of such structures. In this task these interactions will be studied, the effect assessed and control technology developed. This work will be directed by the MSFC.

b. The environmental interactions in large spacecraft can be mitigated by techniques such as active charge control devices. An evaluation of of techniques will be conducted to determine the extent that they will alleviate detrimental systems performance. This work will be conducted by AFGL.

5.5 Analytical Investigation

In this technology element models of physical processes and engineering design tools will be developed. Models of individual interactions would be developed to identify critical parameters. These would be incorporated into a general engineering analytical tool (or tools) to aid in designing systems to withstand detrimental environmental interactions.

The specific tasks and agencies are:

5.5.1 Task 1: Basic Plasma Phenomenological Modelling

In this task the basic plasma phenomena necessary to evaluate environmental interactions with spacecraft systems will be modelled. These phenomena will include ram/wake velocity effects, plasma sheath effects and magnetic field effects. Since this modelling will incorporate the capabilities of several AF and NASA centers, the task will be coordinated by the Steering Committee.

5.5.2 Task 2: Discharge Modelling

In this task models of discharge phenomena will be developed. The work will be conducted by JPL.

5.5.3 Task 3: System Level Analytical Models

In this task analytical models will be developed to support design of mission spacecraft for the mid to late eighties. These design tools will incorporate the interaction models developed in Task 1 and will be capable of evaluating the impact of the environmental interactions and of assessing means of minimizing detrimental interactions. The following models will be developed.

a. Large Space Structures. This model will evaluate the interactions between the large space structures and the space environment. It will be developed by AFGL.

b. Large, High Voltage Power Systems. This model will evaluate the interactions that result from the operation of high voltage systems on spacecraft. It will be developed by the LeRC.

5.6 Space Flight Experiment Planning and Evaluation

The results of the ground technology program must be verified in the actual space environment. To accomplish this, reasonable space flight experiments must be planned and evaluated. It is anticipated that these experiments will be conducted as Shuttle payload experiments or as secondary payloads on approved missions (such as flight demonstrations of large space structures). Close liaison will be maintained with the NASA Shuttle Project Office and with the AF Space Test Program Office to maintain cognizance of flight opportunities. At this time it is not possible to specify the number and types of experiments that will be required; they will be the logical outgrowth of this technology investigation as it progresses.

All agencies participating in this investigation will assist in the planning and evaluation of flight experiments. The Steering Committee will coordinate this activity.

5.7 Design Guidelines and Test Standards

Design Guidelines and Test Standards will be issued and updated as this program develops. These documents will summarize the existing state-of-the-art of the various interactions being studied. Guidelines to be used in designing systems for space applications and test criteria for verifying conformance will be delineated. All participating agencies will submit their contributions for compilation by the Steering Committee. The LeRC will be responsible for issuing the Design Guidelines Document and AFGL will be responsible for issuing the Test Standards.

5.8 Identified Organizational Responsibilities

a. Steering Committee:
- -Overall coordination and planning of the investigation
- -Incorporation of user requirements into the investigation
- -Coordination of basic plasma phenomena modeling
- -Coordination of space flight experiment options
- -Conduct annual meeting and issue minutes

b. AFGL:
- -AF point of contact
- -Coordination for AF
- -Issue test standards document
- -Natural environment engineering specification
- -Techniques for mitigating systems limiting effects
- -Environmental impact
- -Plasma sheath growth experimental studies
- -Large Space Structures analytical modeling

e. AFWAL:
- -Development of new or modified materials
- -Large high voltage power system studies
- -Structure concept definition
- -Analytical design tools

d. RADC:
- -Perform penetrating radiation effects studies on materials

e. LeRC:
- -NASA point of contact
- -Coordination for NASA
- -Issue design guidelines document
- -Basic interaction experimental studies
- -Enhanced environment - system experimental studies
- -High voltage system analytical model

f. JPL:
- -Planetary environment specification
- -Material property measurements
- -Evaluation of sensor performance
- -Experimental and analytical discharge studies

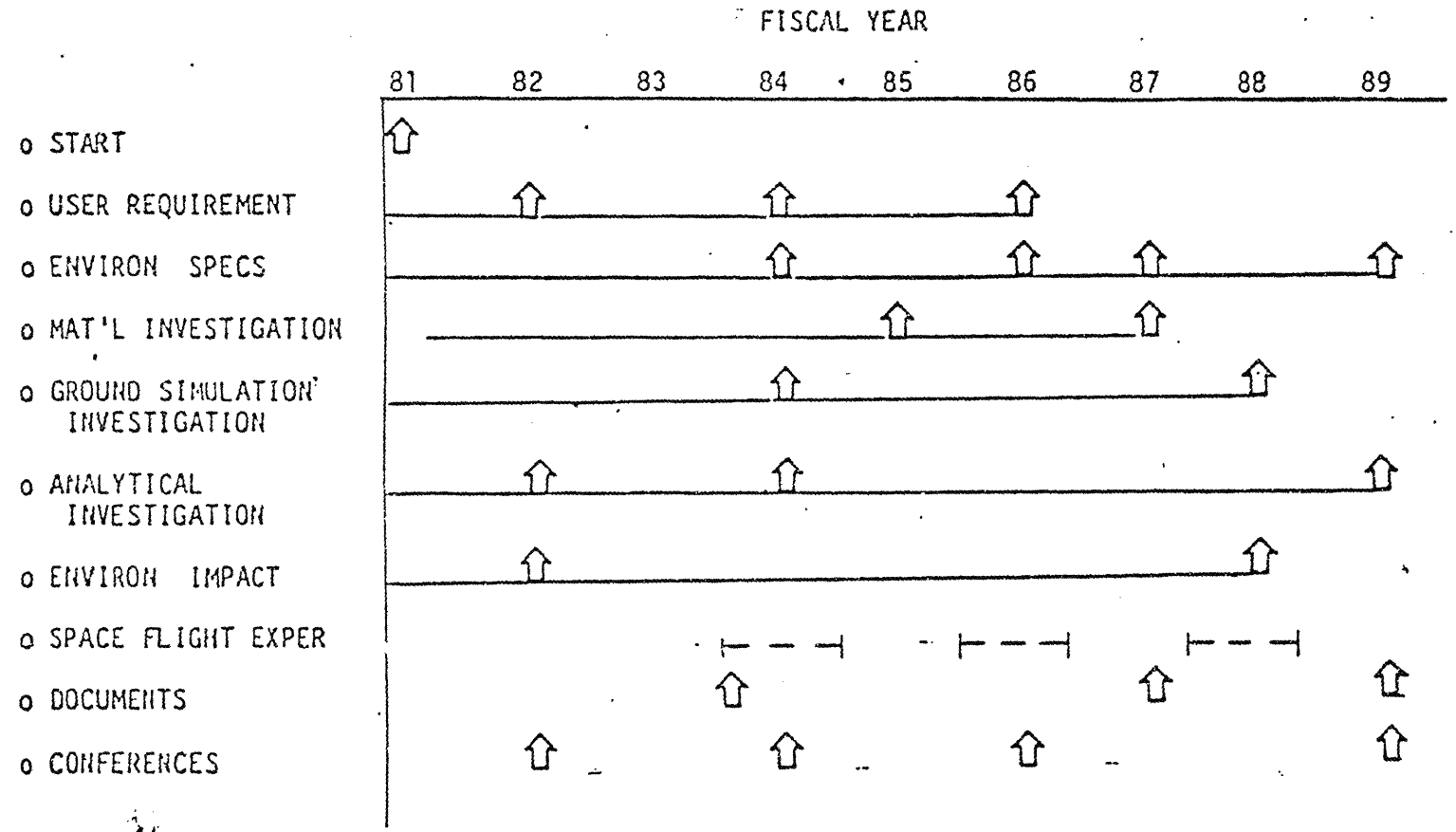
g. JSC:
- -Plasma sheath growth experimental studies
- -Large high voltage system experimental studies

h. MSFC:
- -Ram/wake and magnetic field experimental studies
- -Large structure experimental studies

6.0 RESOURCE REQUIREMENTS

Resource requirements are listed in Table I. The estimated NASA resource requirements will be approved and allocated by OAST for NASA; while AF resources will be approved and allocated by AFSC.

SPACECRAFT-ENVIRONMENT INTERACTIONS
MILESTONE SCHEDULE



RESOURCE REQUIREMENTS[1]

	FY 81	82	83	84	85	86	87	88	89	TOTAL
NASA FUNDING[2]	1.4	1.6	1.8	1.8	1.6	1.5	1.1	.6	-	11.4
MANPOWER	31	35	38	38	36	32	25	15	-	250
AF6.2 FUNDING[3]	1.3	1.8	1.8	1.9	1.9	2.0	2.0	1.9	1.5	16.1
MANPOWER	7	14	13	11	11	12	12	11	11	102
AF6.3 FUNDING[4]	-	0.9	2.0	3.4	2.9	3.0	2.8	2.1	1.6	18.7
MANPOWER	-	8	8	8	8	8	8	8	8	64

NOTES:
1. Funding in $M (Constant FY 79 Dollars), manpower in manyears.
2. Does not include space flight experiments.
3. Includes AFGL, AFWAL and RADC 6.2 funds.
4. Salary reimbursement included.

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